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Experimental investigation on performance of milling operation using vegetable oil based nano cutting fluid and its process parameters optimization using Taguchi and Anova

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ABSTRACT

Cutting fluids are mainly used to increase the quality of machining and productivity. Nano cutting fluids are the combination of base cutting fluids and nano particles. The present study deals with milling of EN8 steel with three different lubrication conditions like dry, machining with water soluble oil and machining with vegetable oil based nano cutting fluid. The Nano cutting Fluid developed by using Refined Corn Oil as a base fluid and the CuO Nano Particles with a weight percentage of 0.3% dispersed by the use of ultrasonicator. The Taguchi and ANOVA techniques used in this investigation to identifying the optimum Process parameters for milling the Keyways in the EN8 Steel used for the motor and pump shafts. The obtained results of tool wear and surface finish during machining under the use of common machining parameters are compared and found that the machining performance of vegetable oil based nano cutting fluid is higher than the dry, mineral oil based cutting fluids.

Key Words: Corn oil, EN8 steel, Nano cutting fluid, Tool wear, Taguchi and Anova

1. INTRODUCTION

Cutting fluid is specially designed for metal working and machining processes. The primary function is cooling and lubrication. Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing work piece thermal deformation, improving surface finish and flushing away chips from the cutting zone. The performance of the machining is based on the type of cutting fluid and the method of application. Thermal conductivities of nanoparticle fluid mixtures are higher than those of the base fluids and reported that Al_2O_3 particles at a volume fraction of 3% can increase the thermal conductivity of water by 20%. The thermal conductivity of nanoparticle fluid mixtures increases with decreasing the particle size and the dispersion technique [1]. Adding nanoparticles to the conventional cutting fluid greatly enhances its wettability, thermal properties, lubricating characteristics. There is a reduction of 50% and 30% cutting force and 54.5% and 28.5% reduction in the Ra value of the machined surface when compared to dry machining [2].Viscosity of the nano fluids based on the concentration of nano particles added with the base fluids [3]. The performance of the vegetable oil based metal working fluids higher than the mineral oil based cutting fluids while machining ferrous and non ferrous materials. Most of the studies were found that use of vegetable oils reduce the cutting force and improve the tool life. Finally, the reviews revealed that the vegetable oils have large scope to utilize them as metal working fluids [5] [7] [8] [16] [17]. By selecting and using the optimum parameters produce better results in the end product as well as improve the performance of machining operations. It was clearly revealed that the cutting feed is the dominant factor in surface finish of the end products [6].The cutting force and the power required for machining is reduced by using the nanolubrication oil [9].The tools wear and tool life in milling operations mainly based on the cooling and lubrication conditions of tool exposed. The experimental results reveal that the application of minimum flow of cutting fluid produces higher tool life and material removal rate [10] [12] [13] [14]..Addition of CuO nano particles improve the anti wear and friction reduction properties of base fluids thus resulting in improvement of tool life and lesser tool wear [18] [19]. The present work deals with Synthesizing of new eco-friendly vegetable oil based Nano cutting fluid for machining and investigating the machining performance under different cooling conditions. The synthesized nano fluid contains the mixture of 0.25% volume concentration of CuO nano particles of 10-120 nm in size with the corn oil. It is investigated to understand the effect of cutting fluid on surface roughness, tool wear in the milling operation under different cooling conditions like Machining under dry condition, Machining with the conventional cutting oil and machining using nano cutting oil, The performance of the synthesized Nano cutting fluid is evaluated by comparing the results of the surface roughness of the machined parts and the tool wear of the cutting tool.

2. EXPERIMENTAL PROCEDURE

A. Nano cutting fluid

This present work proposed a nano cutting fluid that contains refined corn oil and copper oxide nano particles with a volume fraction of 0.25%. Ultra sonicator is used to mixing and suspending the nano particles to the base fluid and the sonification time is limited to 40 min, for avoiding the agglomeration of particles SDS surfactant is used.

B.Work material and tool details

Commonly known EN8 steel shaft was used as a work piece material with the dimensions of 38 mm in diameter and 150mm in length. The work materials used in experiments are from the same conditions that are mentioned previously. The tool used in the work is ATC HSS end mill of 10 mm diameter with two flutes.

Table I Chemical Composition and Properties of EN8 Steel

C	Si	Mn	S	P
0.44	0.4	1.0	0.05	0.05
Mechanical properties				
Tensile stress	Yield stress	% of elongation	Hardness	
850 N/mm^2	465 N/mm^2	16%	255BHN	

C. Cutting conditions and Experimental design

Optimizing the cutting parameters taguchi technique was used, L9 OA was used as the experimental design. The spindle speed, feed rate, depth of cut was used as the process parameters. The experimental setup is shown in fig.1 the machine used is a universal milling machine (BFW-UF2) it has a maximum spindle speed of 2000rpm. To investigate the performance of the cooling conditions during the machining keyway milling is carried out over the work piece and the surface roughness, tool wear was measured. The machining parameters were selected based on the tool manufacturer's recommendations. The standard key way dimensions 10x8x100 mm were selected as per IS 2048-1975 and IS 2710-1975.

Table II Process Parameters and levels

Levels	Spindle speed (rpm)	Feed rate(m m/min)	Depth of cut(mm)
1	355	16	0.3
2	500	20	0.6
3	710	25	0.9

D.Taguchi Design of Experiment:

Taguchi technique is one of the powerful optimization tool used in various applications for obtaining the optimum performance parameters. From the taguchi technique we have calculate the parameters that posses a significant effects over the responses

of the output by calculating the S/N ratio. As we can see mostly all the Manufacturing processes deals with reducing the surface roughness as well as the tool wear for getting the maximum level of profit and the best quality in manufactured products, for the application of the present key way also discuss the same, for that S/N ratio was selected as smaller is better. The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the smaller-is-better S/N ratio is: S/N = ・10・log(・・Y^2)/n)Where Y = responses for the given factor level combination, n = number of responses in the factor level combination.

E.ANOVA:

The analysis of variance is used to test the design parameters and to identify which parameters affect majorly over the machining performance. ANOVA helps to determine the interaction and contribution of relative parameters that controls the output response of the experiment conducted based on the design.

F.Measurement Procedure:

The performance of the cooling conditions was determined by the aid of measuring surface roughness Ra and the tool wear V_B max. The average surface roughness was measured by using stylus type Mitutoyo surftest SJ-201P, the surface roughness values were measured in 10 places of the machined surface and the average value taken as the final value for each time. While considering the tool wear the average material loss in the flank has been taken as the failure of the tool so flank wear considered as a parameter for determining the performance of cooling conditions, measuring the flank wear tool makers microscope (metz-1395) with the magnification range of 30X was used. The allowable flank wear according to ISO 8688-2, 1989 was 0.3 mm and maximum wear of 0.6 mm has taken as tool failure criteria. For all the three cooling conditions each 200mm length of machining the tool dismantled from the tool holder and Flank wear was measured.

3. RESULTS AND DISCUSSIONS

The machining conditions and the parameters were followed as per the experimental design for the milling process of keyway milling under the application Nano cutting fluid. The Nano fluid was supplied through gravity supply system specially designed with flow of 1.5 litres per minute. Flood type coolant supply method was used for conducting the Experimental procedure. The Experimental Results were plotted and discussed in detail for obtaining the optimum process parameter's and the tool life was evaluated and compared with the theoretical values calculated from the Taylor life equations. The experimental investigation on performance of milling operation over EN8 Steel with End milling cutter during the key way milling operation was optimized the machining parameters and the higher surface finish, lower tool wear were identified by using the taguchi method. The best parameters were predicted from the S/N Ratio, the higher values getting from the S/N Ratio is the most significant factors for the output responses. The output responses can be calculated and concluded that the spindle speed is the most significant factor than the other two parameters for considering the surface roughness and the feed rate is the highly affecting parameter than the spindle speed and (doc) over the tool Wear.

Table III Experimental results

Test no	Spindle speed (s) in rpm	Feed (f) in mm/min	Depth of cut (d) in mm	Surface roughness Ra in (µm)	Tool Wear (w) in mm
1	355	16	0.3	1.54	0.005
2	355	20	0.6	1.45	0.010
3	355	25	0.9	1.78	0.020
4	500	16	0.6	1.51	0.005
5	500	20	0.9	1.60	0.010
6	500	25	0.3	1.33	0.015
7	710	16	0.9	1.19	0.005
8	710	20	0.3	0.83	0.005
9	710	25	0.6	1.01	0.010

Table IV Response table for S/N ratio (Ra)

Level	spindle speed	Feed rate	depth of cut
1	-3.99539	-2.94696	-1.53634
2	-3.37966	-1.89711	-2.29778
3	0.00702	-2.52395	-3.53391
Delta	4.00242	1.04986	1.99758
Rank	1	3	2

Table V ANOVA table for Ra

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	2	0.5694	0.5694	0.2847	91.84	0.011
Feed rate	2	0.0224	0.0224	0.0112	3.61	0.217
Depth of cut	2	0.1322	0.1322	0.0661	21.32	0.045
Error	2	0.0062	0.0062	0.0031		
Total	8	0.7302				

Table VI S/N Ratio of tool wear

Level	spindle speed	Feed rate	depth of cut
1	40.00	46.02	42.84
2	40.83	42.01	42.01
3	44.01	36.82	40.00
Delta	4.01	9.20	2.84
Rank	2	1	3

Table VII ANOVA table for Tool Wear

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	2	0.0000389	0.0000389	0.0000194	7.00	0.125
Feed rate	2	0.0001556	0.0001556	0.0000778	28.0	0.034
Depth of cut	2	0.0000222	0.0000222	0.0000111	4.00	0.200
Error	2	0.0000056	0.0000056	0.0000028		
Total	8	0.0002222				

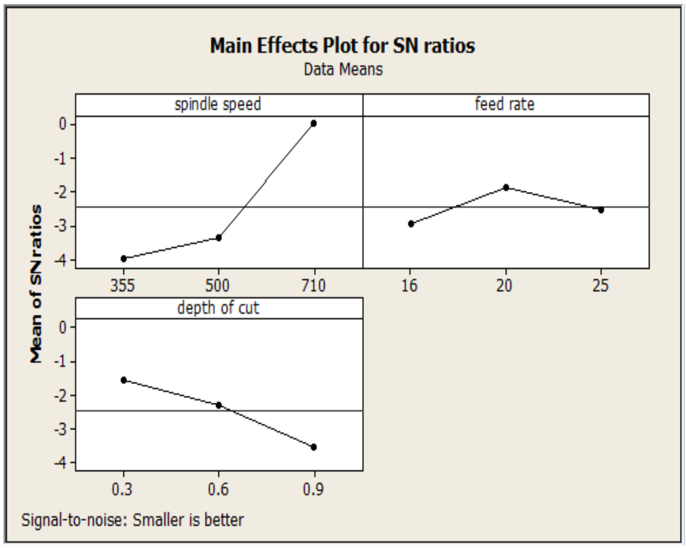

Figure 1 Main effects plot for Ra

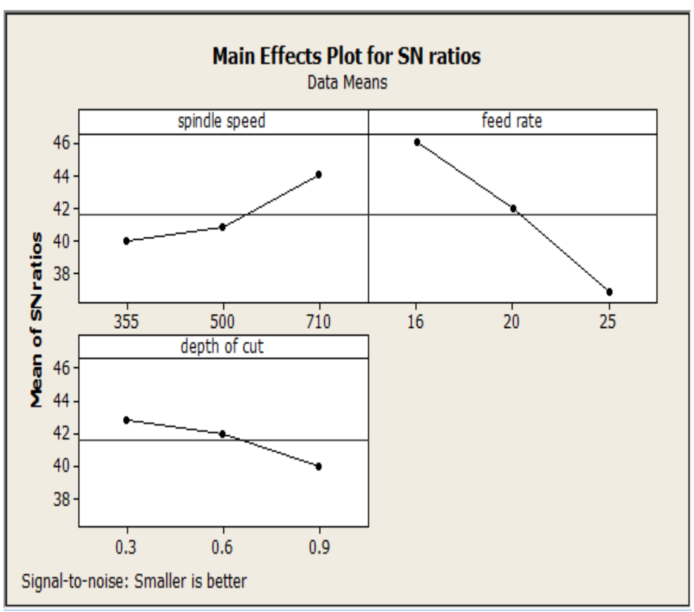

Figure 2 Main Effects plot for Wear

The Results observed from the Taguchi S/N Ratio were analysed by using the ANOVA method and by using the P value (significant factor). For the most significant conditions P value was selected a less than 0.05 commonly. The ANOVA table collectively consists of P, S, R^2, Adjusted R^2 values. From the main effects plot of S/N ratios of data means it can be clearly identified that the cutting parameters for produce best surface finish were spindle speed of 710 rpm, feed rate 20 mm/min and depth of cut 0.3 mm, while considering the tool flank wear the spindle speed of 710 rpm, feed rate 16mm/min, doc 0.3 mm were the best combinations of this present work.

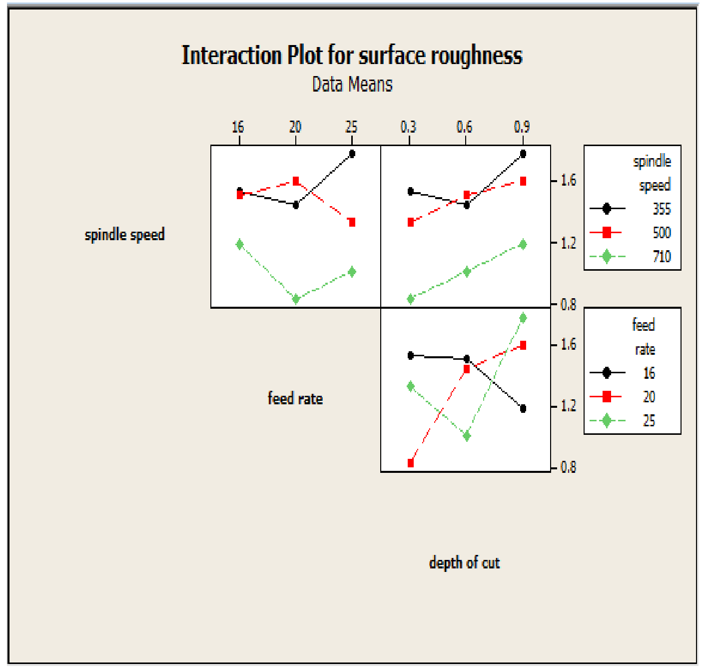

Figure 3 Interactions plot for Ra

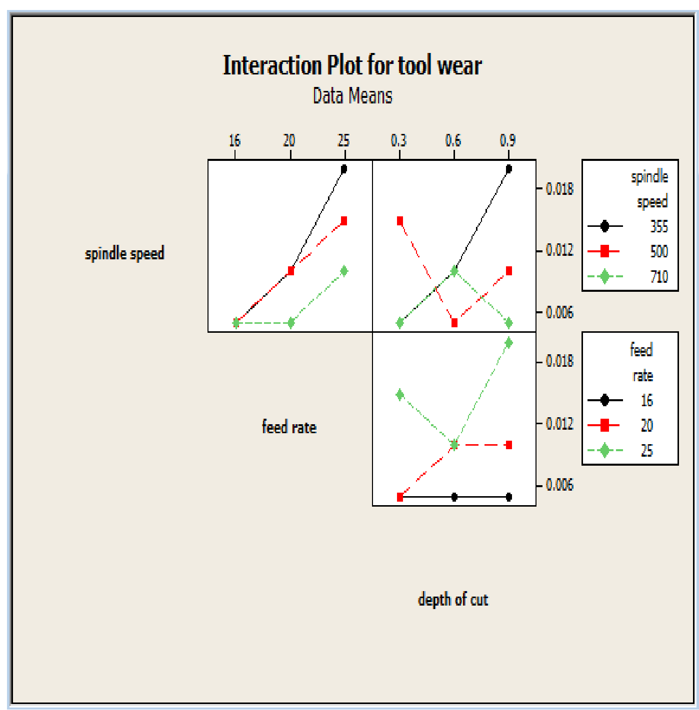

Figure 4 Interactions plot for Flank Wear

4. CONCLUSIONS

This Experimental study discussed the application of Taguchi and ANOVA methods for investigating the machining parameters and their influences on the surface finish and the tool wear over the EN8 steel during key way milling by applying Nano cutting fluid as a coolant. The optimized parameters were predicted by using the taguchi method and their level of importance on the surface roughness and Tool flank wear was determined by Analysis of variance. From this experimental investigation the following conclusions were drawn.

1. The performance of the Nano cutting fluid was higher than the dry and conventional cutting fluids used in the keyway milling operations. This investigation revealed that the applications of vegetable oils produce better results than conventional coolants.
2. The optimum milling condition for considering the surface roughness was spindle speed 710rpm, feed rate 20mm/min and depth of cut 0.3mm.
3. The optimal cutting condition for Tool Wear was spindle speed 710 rpm, feed rate 16 mm/min and depth of cut 0.3 mm.
4. From the Taguchi and ANOVA analysis it was found that the cutting speed is statistically significant for the surface finish and the feed rate followed by spindle speed influencing the tool wear.

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